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COMMERCE

AND

PHYSICAL FEATURES OF THE GREAT  
LAKES.

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BY

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## COMMERCE AND PHYSICAL FEATURES OF THE GREAT LAKES.\*

BY MAJOR HENRY A. GRAY, C.E.

The constantly increasing importance of the Great Lakes for the purpose of commerce having recently caused considerable public attention on both sides of the Atlantic, it is thought that this paper on the commerce and physical features of these waters, prepared from notes and observations made from time to time during the past fifteen years, and from information gathered, during that period, by the writer, while filling the position of engineer in charge of the Public Works of Canada in the lake district, will be of interest. The average season of navigation on the lakes is about 220 days. In order to give an idea of the extent of the commerce on these lakes, it is shown that the annual average net tonnage for the last five years of the Suez Canal—a world's channel of commerce, and open every day in the year—was 6,983,167 tons; the annual average net tonnage of the lock and canal, at Sault Ste. Marie, for the same period—open only an average of 220 days in the year—was 6,821,062. The registered American tonnage of the lakes, June 30th, was 1,154,878 tons; 1,592 steam vessels, representing 736,751 tons, and 2,008 sail, 418,118 tons. The tonnage has more than doubled in the last five years, the increase being almost exclusively in steel steamships of 1,500 to 2,500 tons register. The number of Canadian vessels on the lakes is 647, tonnage 132,971; valuation, \$3,989,130. The total of coast and inland shipping registered in Canada is 7,153 vessels, of 1,040,481 tons register, valued at \$31,213,430.

The sailing vessel has almost disappeared from the lakes. The square-rigged ship is no longer seen, and only a few of the great cargo-carrying schooners are left. The sailing fleet was succeeded by the "propeller," as it is known locally, with its tow of one or

\*Presented before the Canadian Society of Civil Engineers.

more consorts, and it, in turn, is giving way to the modern steamer, maintained at little more than one-half the cost, while having a carrying capacity quite as great, a speed double that of the propeller and consort, and making two or three round trips for one of the tow. Of large capacity and great power, regardless of wind or weather, the steamers of the prevailing type bear their cargoes to and from ports a thousand miles apart, with the precision of railroad trains, each of them transporting at once more than ten ordinary freight trains.

The work of this lake shipping is given approximately by the United States census report, 1890. The freight movement in 1889 on all the lakes was estimated by that report at 53,424,432 tons. The tonnage put afloat since then has increased this movement to 63,240,514 tons. Estimates only can be given, because at one point only on the lakes, Sault Ste. Marie, is there an official record made of tonnage movement. The movement through the Detroit river alone, in 1889, was estimated at 36 203,586 tons. The total entries and clearances, foreign and coastwise, for the port of London that year (1889), were 19,245,417 tons; of Liverpool, 14,175,200 tons. The estimate of the tonnage movement through the Detroit river, in 1889, was 3,000,000 tons above the combined foreign and coastwise tonnage of the ports of London and Liverpool.

The rapid growth, too, of steam transportation, and the competition of lake lines with the railways, have caused continued reductions in the cost of transportation. The cost per ton per mile of carrying freight, an average distance of eight hundred miles, was one and one-half mill in 1889. The value of all the cargoes—27,500,000 tons—carried on the lakes during that year was over \$315,000,000. Had this been carried at railway rates, the cost to the public would have been over \$143,000,000; by the lake rates it was about \$23,000,000 only; so that transportation on the lakes saved to the public about \$120,000,000 in one year. But, as to a large portion of this tonnage, any possible cost on wheels would not have permitted it to move at all. In such a case, its production at the point of origin would, of course, have been impossible. That, in turn, would have halted the pioneer emigrant this side of the richest areas of the continent.

The average distance for which freight on the lakes is carried is 566 miles. From this, the Census Bureau estimates the ton mileage for the season of 1889 to be 15,518,360,000 tons miles. The aggregate ton mileage of railways for the year ending June 30th, 1889, was 68,727,223,146, which shows the ton mileage of the lakes is nearly one-fourth of the total ton mileage of railways in the United States. In no other way could the relative importance of lake commerce be more effectively shown.

During the season of 1879, grain was shipped from Chicago to Liverpool for 17 cents per bushel, a rate but little greater than was paid for transportation by canal from Buffalo to New York, only ten years before, that is in 1869. In 1890, grain was shipped from Chicago to Liverpool for 9 $\frac{3}{4}$  cents per bushel.

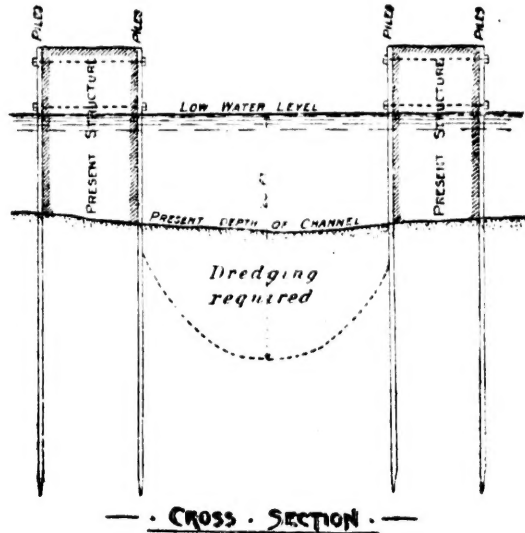
The extraordinary growth in shipbuilding and commerce on the lakes implies corresponding changes of conditions as to population and production along the thousands of miles of their shores and in the tributary country. Such equipment and use of these waters mean industrial activity and large advance in population.

	1880.	1890.
Four cities on Lake Superior had population	5,528	64,147
Four cities on Lake Huron and Lake St.		
Clair .....	181,610	304,863
Twelve cities on Lake Michigan .....	734,196	1,502,663
Seven cities on Lake Erie ..	420,685	675,310
	<u>1,342,019</u>	<u>2,546,983</u>

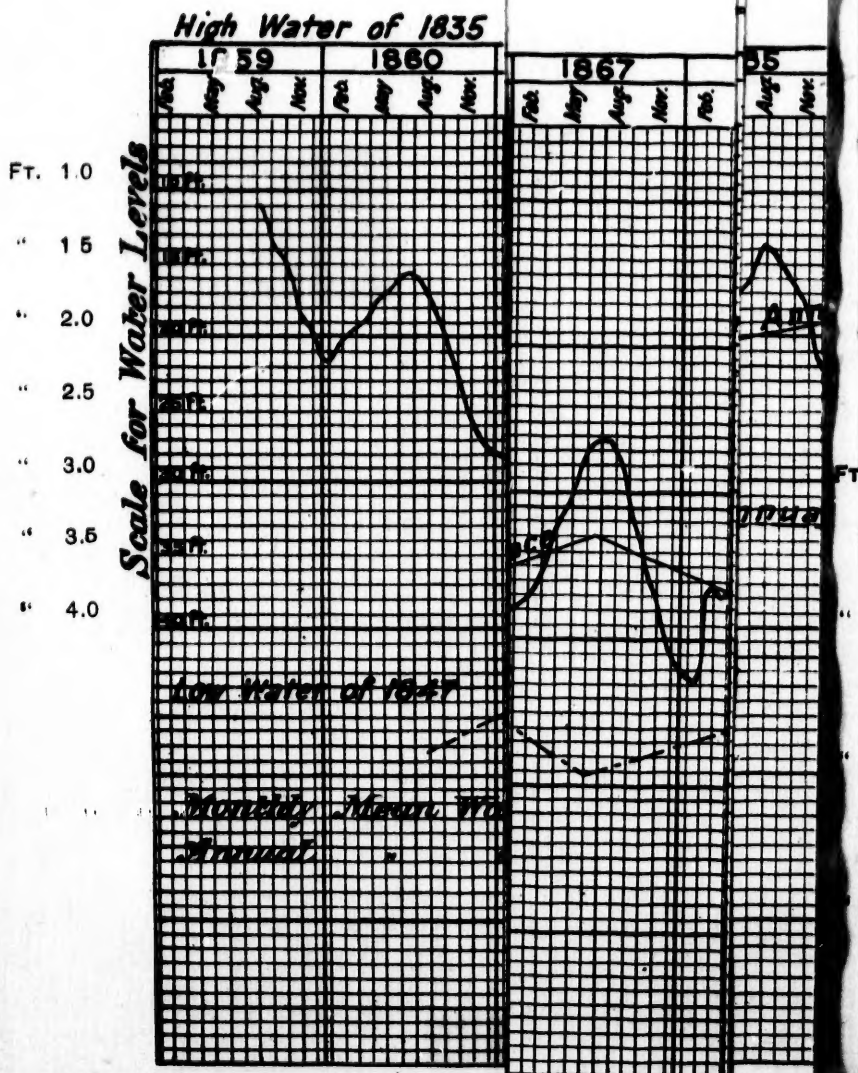
An increase of population in ten years of 85 per cent.

The Government of Canada has expended a large amount of money, in some instances assisted by the municipalities, on these lakes in constructing breakwaters, piers, wharves, and in dredging out approaches to harbors and channels entering same, as well as inner basins for vessels to lie in, both for commercial purposes and refuge. Up to the time of Confederation the amount expended by the Public Works Department of Canada for the above purposes was \$890,699.25, and from that period until the 30th June, 1893, the expenditure was \$3,439,364.63, making a total of \$4,330,063.88. This does not include the construction of a dry dock at Kingston, nor the Canadian canal and locks at Sault Ste. Marie. Owing to the low stage of water in the lakes during the past two

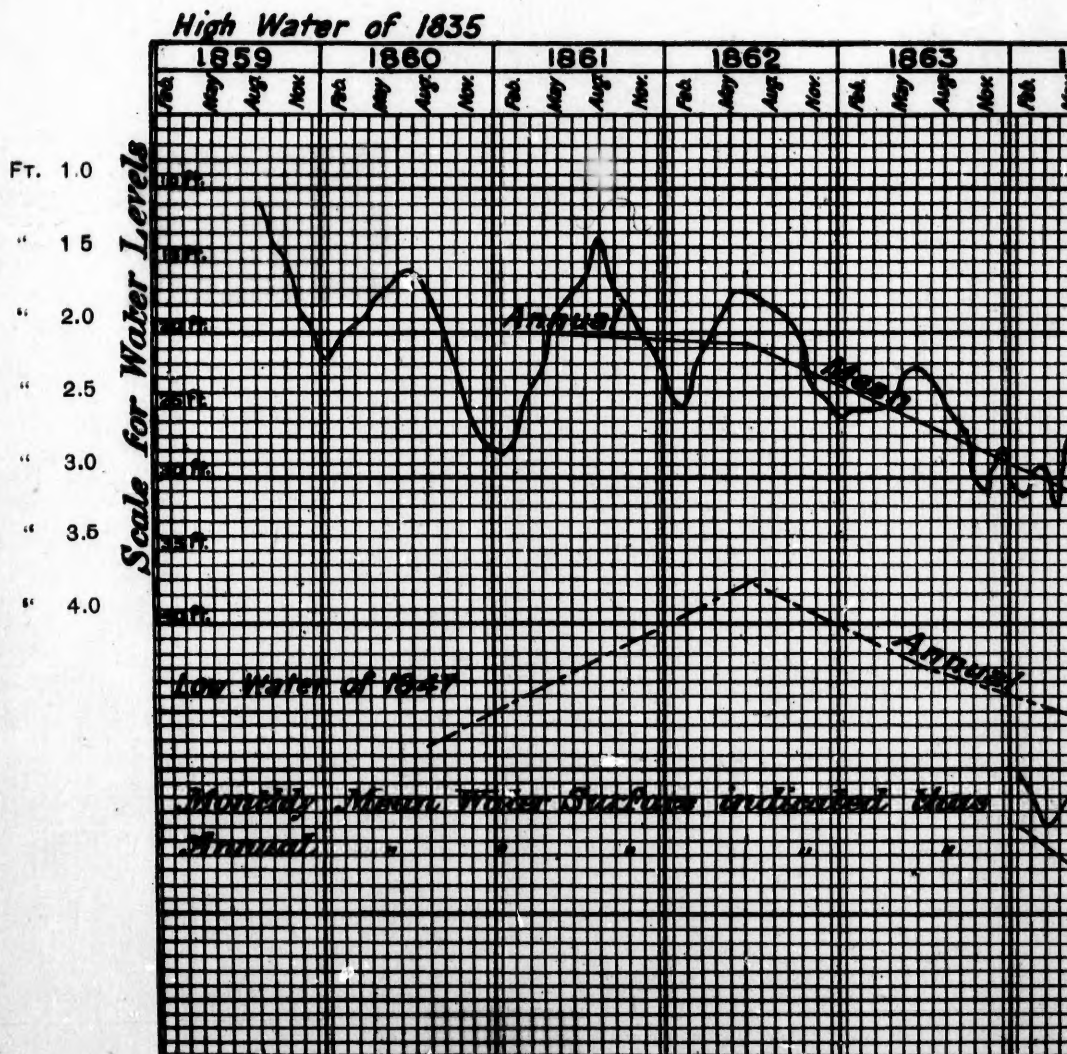
seasons of navigation, considerable demand has been made upon the Department of Public Works of Canada for dredging out channels at the entrance to many of the harbors, and also for a continuation of the dredging inside the harbors, to enable vessels to enter for the purpose of loading and unloading. Care had to be exercised in directing these operations, from the fact that when the present piers and other works were constructed at the several harbors, some years ago, these structures were considered quite safe, and as serving all purposes for which they were intended, if extended and built in from 10 to 13 feet of water, as vessels drawing these depths were the largest afloat. Recent years have developed a much larger capacity in vessels trading upon the upper lakes, and, consequently, a deeper draught. To accommodate this increased size and draught, and even to give access to those of less tonnage during the low stage of water, the dredging required was, in many cases, lower than the foundation of the structures. To obviate the difficulties and danger to the present structures—where the increased depth is required—it has become necessary to protect the piers, etc., by driving sheet-piling along the sides and ends; this method is the least expensive. The sketch below shows the method adopted:—



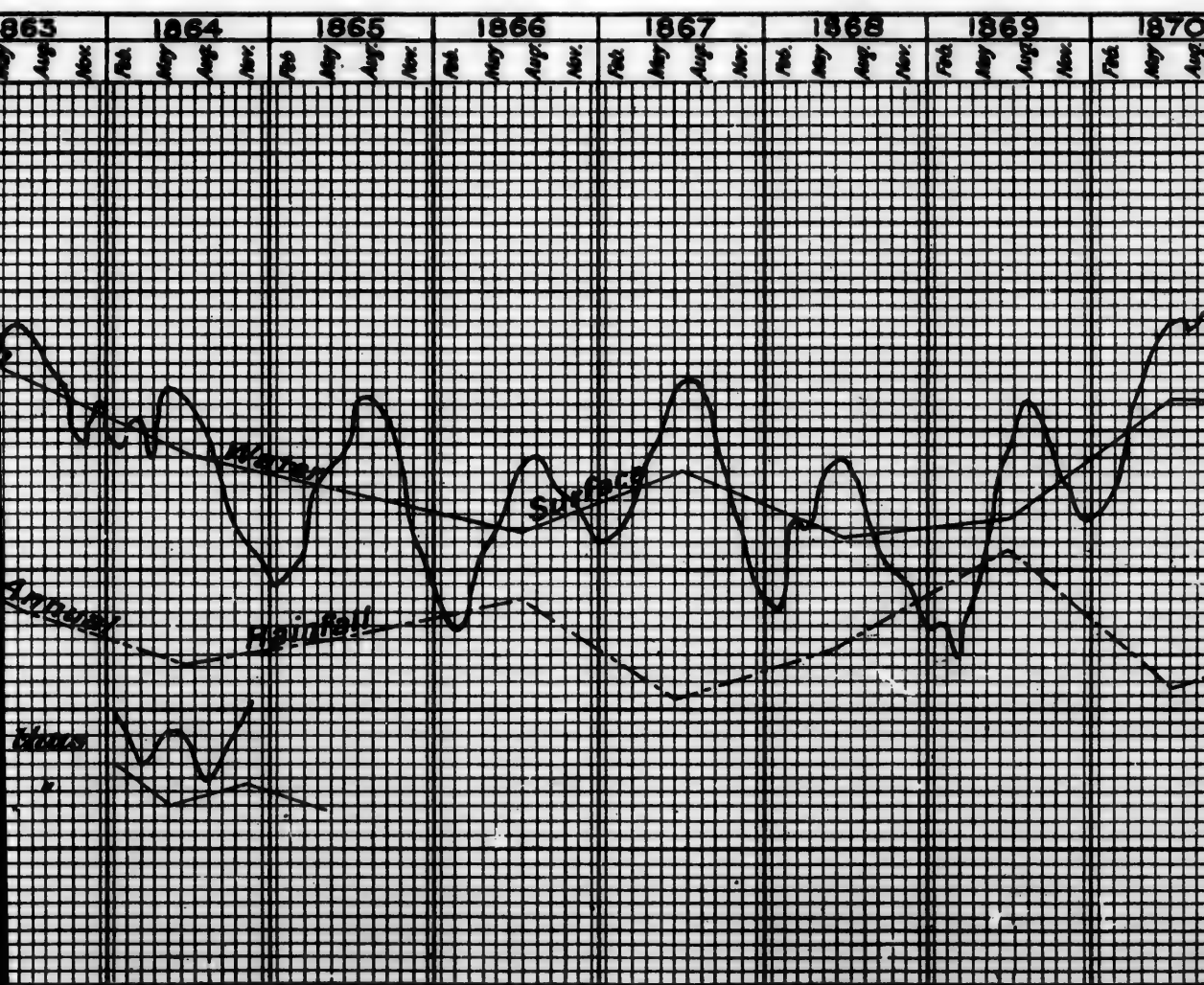
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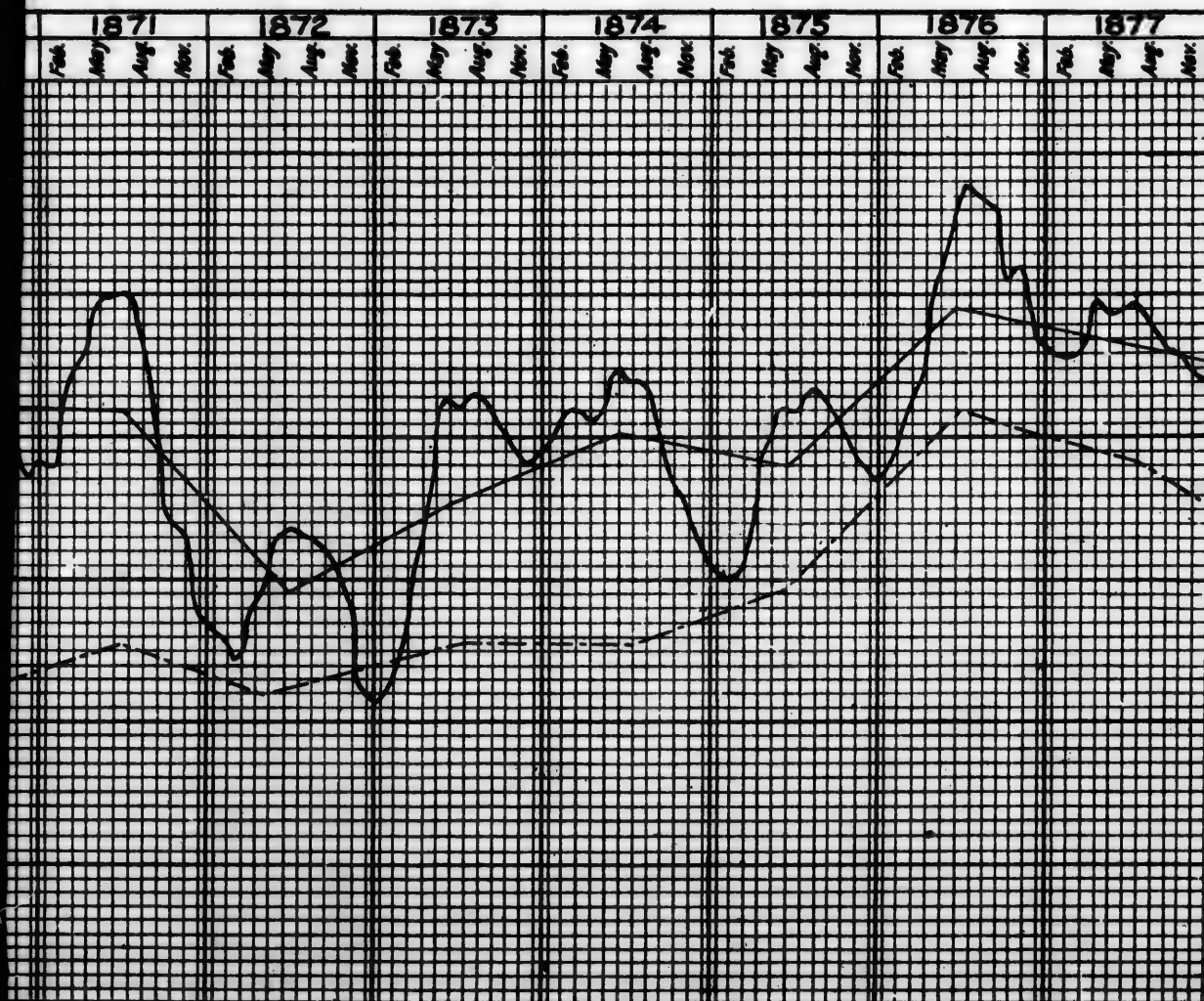
Henry A. Gray



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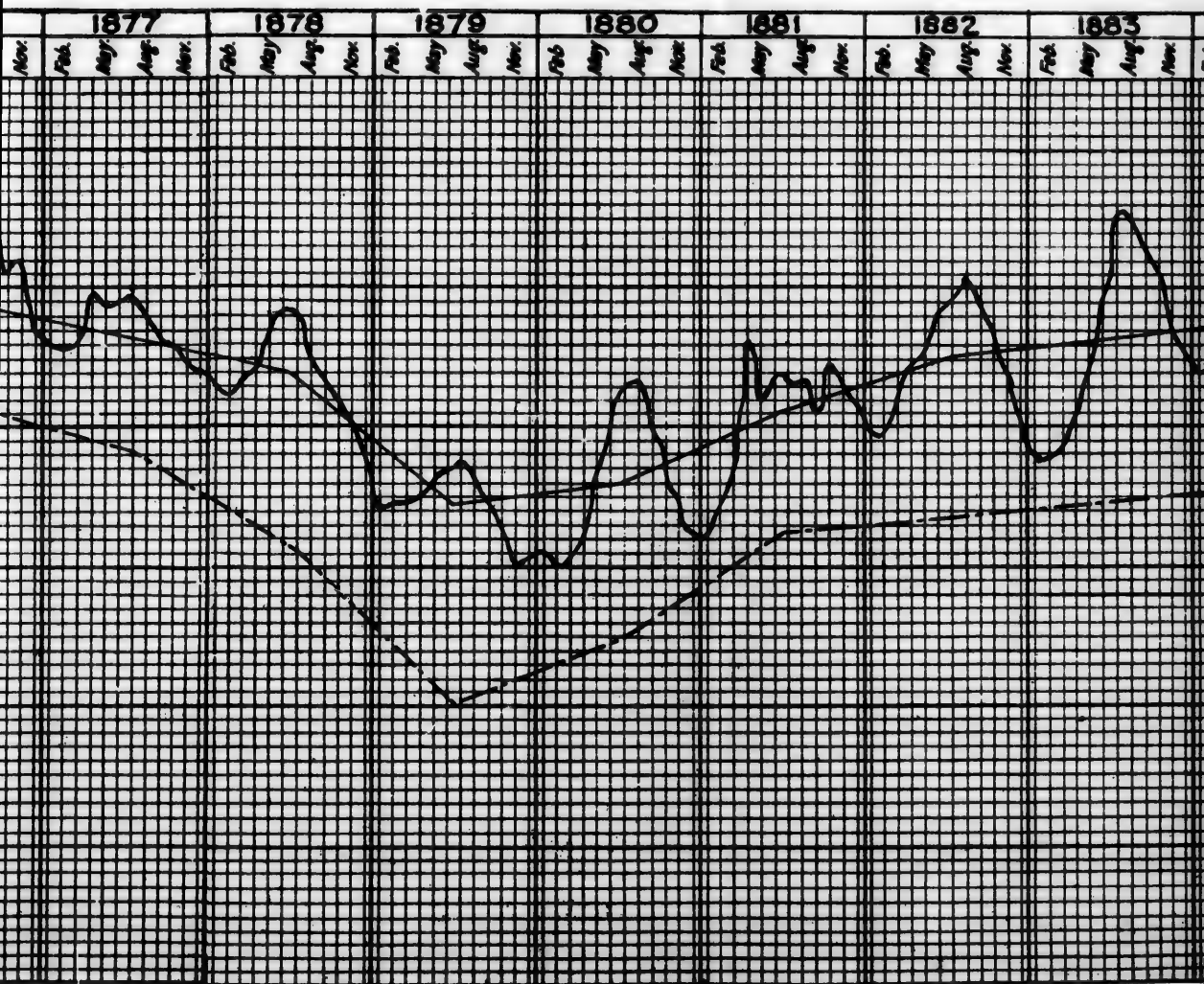


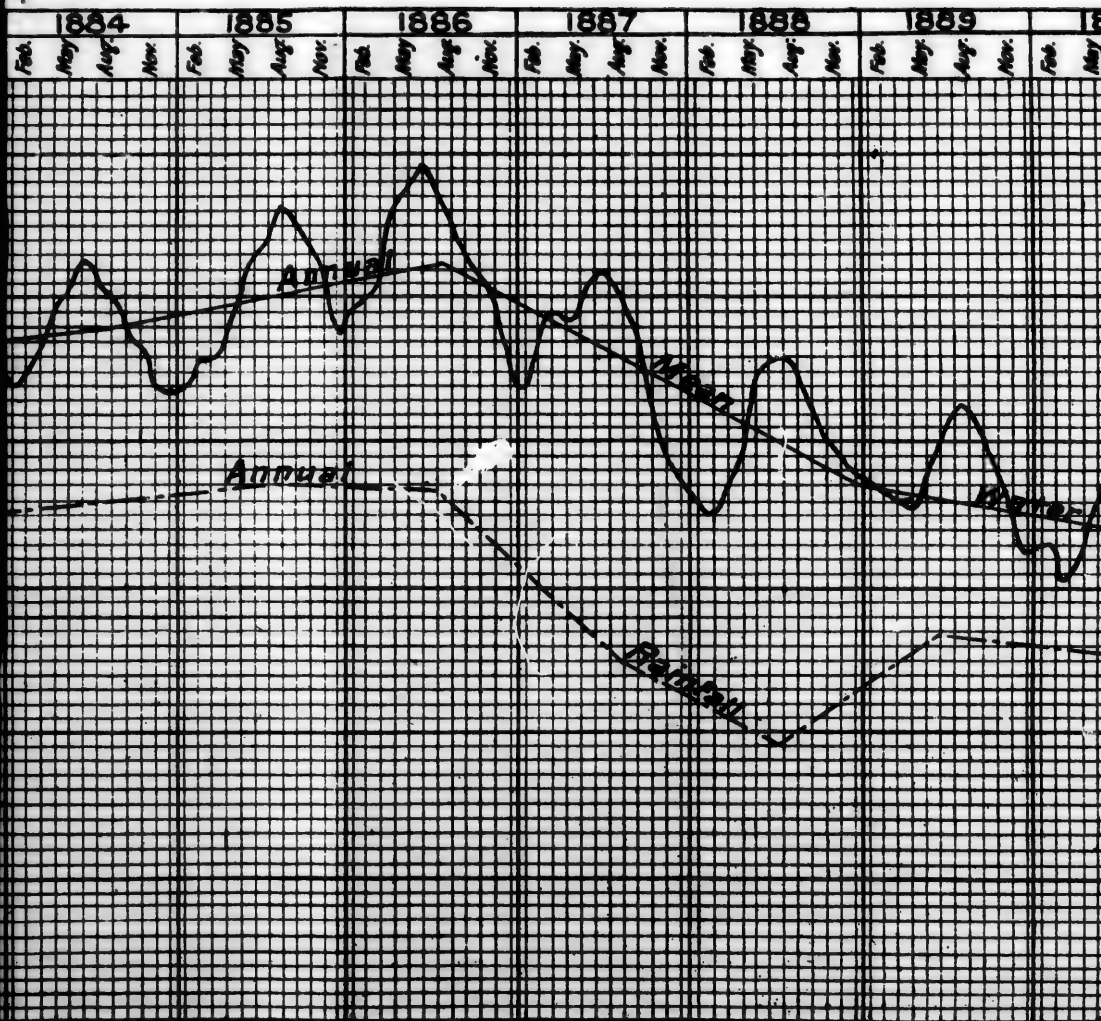
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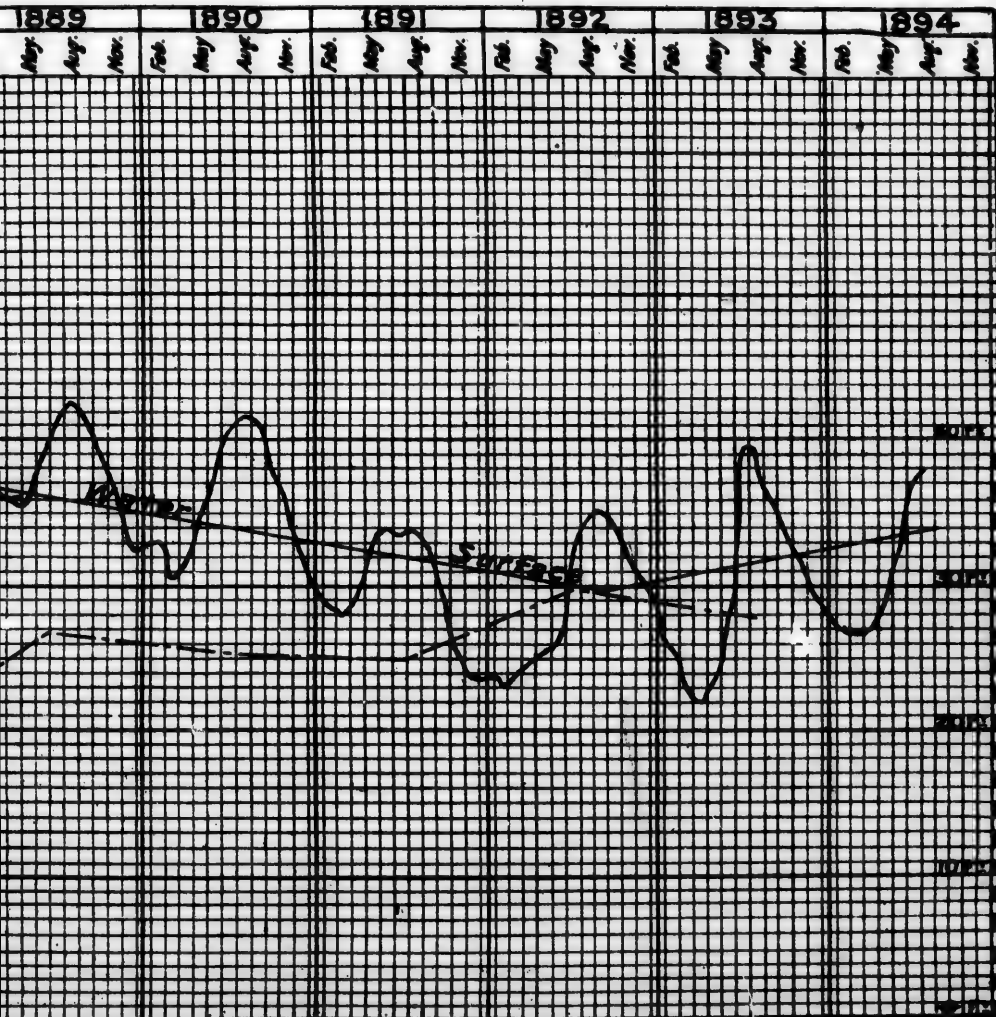
SHOWING

WATER SURFACE AND RAINFALL  
AN AND HURON.





TRANSACTIONS CAN. SOC. C. E.  
VOL IX. PLATE 'V.



Scale for Rainfall

4.0 F

3.0 "

2.0 "

1.0 "

With respect to the low stage of water in the lakes, referred to above as having caused the Department of Public Works of Canada considerable attention and expenditure of money for dredging purposes during the past two seasons, various theories have been advanced to account for the several changes in the water level of the lake; it is, however, well established that the fluctuations are due to the variations in rainfall, as the lake levels approximate closely to those of rainfall and snow. The highest known level occurred in 1838, when Michigan and Huron rose 26 inches above ordinary high stage, and Erie and Ontario 18 inches. The lowest level was in 1819, when Erie fell  $3\frac{1}{2}$  feet below its usual plane. Since the highest water in 1838, there have been alternate periods of descension and ascension of the levels, either five, seven, or eight years in lengths, the seven year period being most frequent. In order to show the fluctuations of the water surface, rainfall, etc., as stated above, the accompanying chart of Lakes Huron and Michigan has been prepared, copied from information compiled from official data, obtained from the U. S. Lakes Survey, and tabulated by Mr. Chas. Crossman, U. S. Engineer at Milwaukee. The chart embraces a period from 1861 to 1894. A careful examination will show that from 1882 to 1888 the surface of Lakes Michigan and Huron was considerably above the mean level. The water, at the present time, is about the average of the period from 1882 to 1887, and judging the future by the past, it is probable that for several years to come there will be no permanent increase in depth. By this chart, the relation between the rainfall and the stage of the lake can be perceived unmistakably in the spring, autumn, and summer of 1876, the remarkable rise of water, culminating in September, 1876, corresponding with a period of heavy rainfall. This period was followed by a few months of light rainfall, during which the water fell rapidly. From this time until December, 1879, the rain, fall was, as a general thing, less than the mean, and the water surface had a downward tendency. In January, 1880, began a period of heavy rainfall and a rise in the water. From June to August, 1881, the rainfall was light and the stage of water a falling one. In September there was the heaviest rainfall known for many years, accompanied by a correspondingly rapid rise in the water.

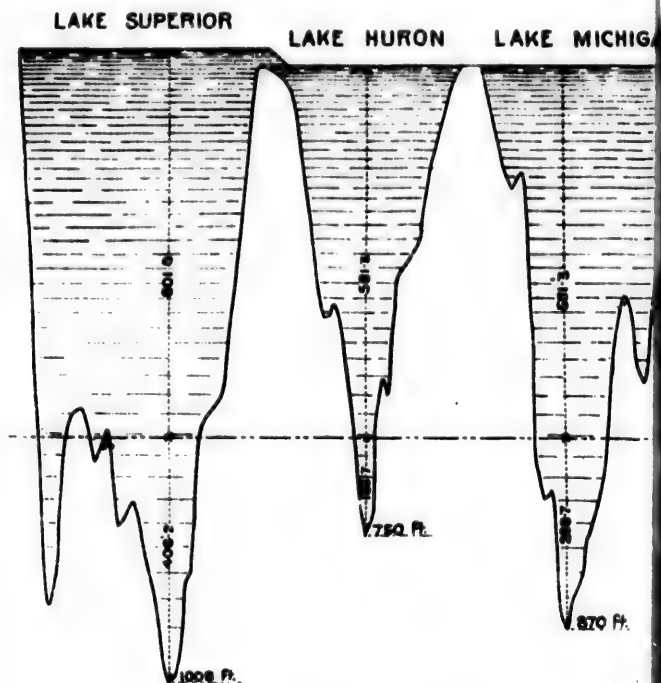
While there is every reason to believe that a winter of continually freezing weather, by retaining the snowfall until the thawing weather of April or May, will tend to raise the summer level of the lake at the expense of the winter level, it is not confirmed to any great degree. The explanation of this is not difficult. A single week of warm weather in the winter, causing the melting of the greater part of the snow, might be preceded and followed by extremely cold weather, giving a low mean temperature for the month; so that a cold winter does not necessarily imply the impounding until spring, in the form of snow, of the winter rainfall. Vessel owners and captains state that the water in the several lakes must have decreased and fallen, as it is now found more difficult to enter the several harbors and navigate the channels. Others have remarked that the deepening of some of the channels lying between the chain of lakes has caused a drainage and lowering of the water in the lakes; others, that the wearing away of the crest of the rock at Niagara Falls has lowered the water above that point.

In making these and other assertions and statements, these persons seem to forget entirely that the vessels used now are larger, and draw from six to ten feet more water than they did some few years ago, and, consequently, require a corresponding greater depth of channel and harbor accommodation. General Poe, Lieut.-Col. of Engineers, U. S. Army, in charge of the Lake District for the American Government, writing upon this subject, states:—"There is no indication anywhere that the waters in the lakes have mysteriously fallen. The long continued series of observation, now available, show that since 1838 the water level has fluctuated within limits somewhat less than 6 feet, and that these fluctuations were due to the greater or less rain and snowfall. It may be considered, as a fact established, that the lakes are simply great pools forming part of the course of a river, and that they conform to all the laws governing the rise and fall of rivers."

In 1881, it was stated by the Toronto newspapers that the level of Lake Ontario had been lowered by work done at the Galops Rapids, in the St. Lawrence river, and that the harbor of Toronto had been damaged by it. It was proved, however, that thirty years before the deepening of the Galops channel was begun, the water

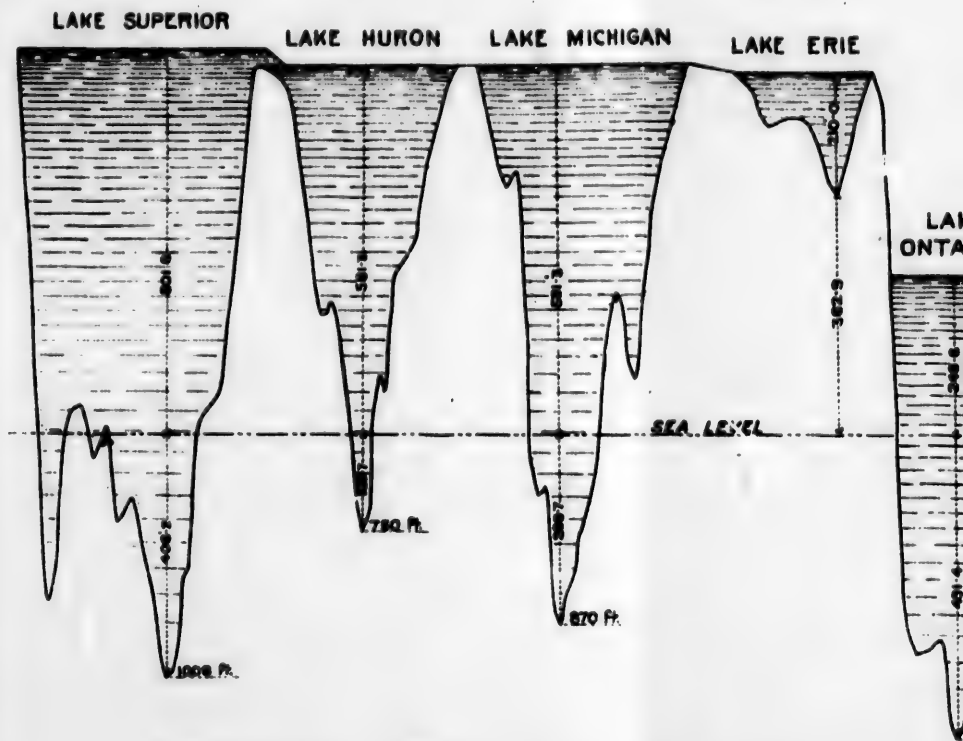


Henry A. Gray.



LONGITUDINAL SECTIONS OF THE  
on the line of deepest water

Henry A. Gray.



LONGITUDINAL SECTIONS OF THE LAKES  
on the line of deepest water.



	Area of Water surface	Area of watershed	Aggregate area of basin
	SQ. MILES.	SQ. MILES.	SQ. MILES.
Lake Superior	31,200	51,600	82,800
Lake Huron	23,800	31,700	55,500
Lake Michigan	22,450	37,700	60,150
Lake Erie	9,960	22,700	32,660
Lake Ontario	7,240	21,600	28,840

was as low in Lake Ontario as it was in 1821. The best authorities on hydraulics show that no harm can result from deepening the several channels, for it is a theory of permanent motion that a change of *regimen* being made at any point of a river, its effect is extended up and down stream, decreasing as it goes until points are reached where it disappears entirely, and the river remains unaffected.

In the following it is endeavored to give a part of the latest and most reliable information relating to the Great Lakes. The lately completed lake surveys made by the United States have reduced to exactness much that was previously only approximate.

The water surface of the Great Lakes, with the land draining into it, presents the total drainage basin of over 270,000 square miles, assembled as follows:

	Area of Water Surface, Square Miles.	Area of Water Shed, Square Miles.	Aggregate Area of Basin, Square Miles.
Lake Superior .....	31,200	51,600	82,800
St. Mary's River .....	150	800	950
Lake Michigan .....	22,450	37,700	60,150
Lake Huron and Georgian Bay.....	23,800	31,700	55,500
St. Clair River .....	25	3,800	3,825
Lake St. Clair.....	410	3,400	3,810
Detroit River.....	25	1,200	1,225
Lake Erie .....	9,960	22,700	32,660
Niagara River .....	15	300	315
Lake Ontario.....	7,240	21,600	28,840
	95,275	174,800	270,075

The combined areas of the lakes exceed the area of England, Wales and Scotland.

The accompanying figure is a carefully drawn chart of the lakes, and compilations showing area of water surface, water shed and aggregate areas of basin; line of greatest depth and longitudinal sections on that line, with heights and depth referred to sea level. The length of shore line of the lakes and their connecting rivers is about 5,400 miles. The elevation of the mean surface of the lakes above mean sea level is as follows:—

Lake Ontario .....	246 $\frac{8}{10}$	feet.
Lake Erie.....	572 $\frac{9}{10}$	"
Lakes Huron and Michigan.....	581 $\frac{1}{10}$	"
Lake Superior.....	601 $\frac{8}{10}$	"

The difference of 20½ feet between Lake Superior and Huron occurs in the rapids of St. Mary's river; the 8½ feet between Lakes Huron and Erie, mainly in Detroit river. The difference of 326 feet between Lakes Erie and Ontario occurs in the vicinity of Niagara Falls, and is principally assembled as follows:—100 feet in the five miles of rapids between Lewiston and the lower Suspension Bridge, 10 feet in the rapids between the Bridge and the Falls, 160 feet at the Falls, 50 feet in the rapids immediately above the Falls, and 6 feet in the upper Niagara river. The mean depth of Lake Superior is about 475 feet; the deepest point marks a depth of 1,008 feet, or 406 feet below the level of the sea. Lake Huron has a mean depth of 250 feet and a maximum depth of 750 feet. Lake Erie is comparatively shallow, having an average depth of less than 70 feet and a maximum of 210 feet. Lake Ontario has a mean depth of about 300 feet and a maximum of 738, or nearly 500 feet below the level of the sea. The channel of the rivers connecting the lakes seldom exceeds the depth of 50 feet. If the lakes could be drained to the level of the sea, Lake Erie would disappear, Lake Huron reduced to quite insignificant dimensions, Lake Michigan to a length of about 100 miles, with a width of 25 or 30 miles, Lakes Ontario and Superior, although with diminished areas, would still preserve the dignity of their present titles as Great Lakes.

A chemical analysis of water taken from the deepest part of Lake Superior failed, under the application of delicate tests, to indicate the presence of salt. The beds of the lakes away from the vicinity of the shore lines, and at depths exceeding 100 feet, are almost invariably covered with clay. Specimens from the deep soundings of Lake Superior were invariably soft clay, varying in color from red to yellow and blue. In the deepest parts, the drabs and bluish tints predominate. The temperature at the deepest points varies little from the mean annual temperature of the surrounding air. The temperature of Lake Superior at depths exceeding 200 feet varies but slightly from 39° F. In Lake Huron, at depths of about 300 feet, the temperatures in the months of June and August were 52° F., while, at a depth of 624 feet, the temperature was 42° F., the surface temperature being 52° F., and the air 64° F. The mean annual rain and melted snowfall of the several lake

basins is as follows : Lake Superior, 29 inches ; Lake Huron, 30 inches ; Lake Michigan, 32 inches ; Lakes Erie and Ontario, 34 inches. This is about equal to 31 inches on the entire lake basin. The following represents the average discharges at the outlets of the lakes : —

Lake Superior, at St. Mary's River.....	86,000 cubic ft per sec.		
Lakes Michigan and Huron at St. Clair			
River.....	225,000	"	"
Lake Erie, at Niagara .....	265,000	"	"
Lake Ontario, at St. Lawrence River.....	300,000	"	"

If the average discharge of the lakes passed through a river one mile wide with a mean velocity of one mile per hour, such river would have a depth of 40 feet from shore to shore.

The volume of water in the lakes is about 6 000 cubic miles, of which Lake Superior contains a little less than one-half. Perhaps a better idea of this volume may be obtained when it is said that it would sustain Niagara Falls in its present condition for about 100 years.

The principal changes in the elevation of the lake surface are those due to the wind and to rainfall.

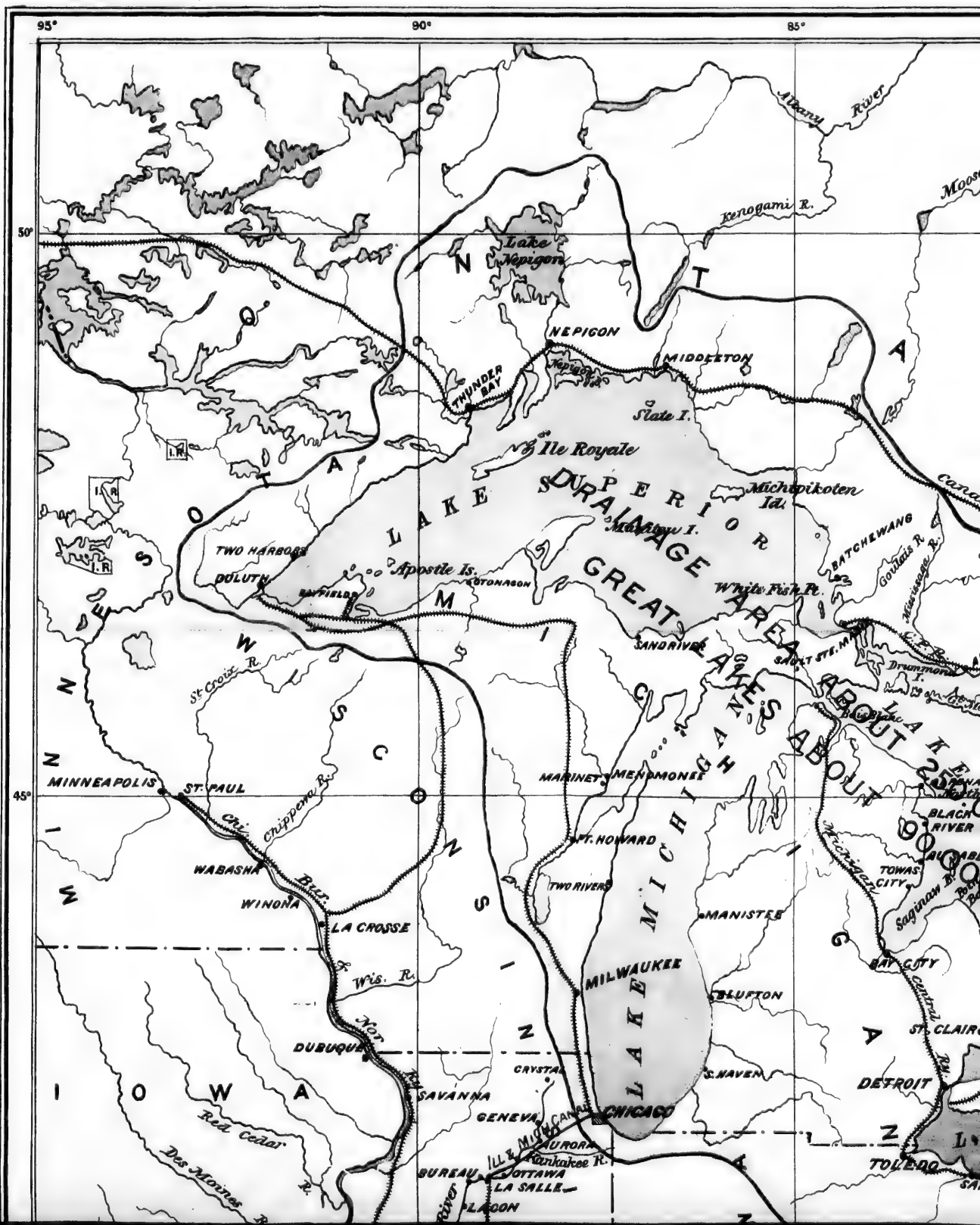
During protracted autumn gales, waves have been observed which, through reliable means, measured from 15 to 18 feet above the normal surface. The second class of variation are those due to rainfall, as before stated. The last ten years show a tendency to irregularities which may be due to changes in rainfall and watershed, produced by the rapid destruction of the forests which, ten years ago, covered the basin of the upper lakes. Observations made by the U.S. Survey have established the existence of small tides which, at Chicago, had an amplitude of  $1\frac{1}{2}$  inches for the neap tide and about 3 inches for the spring tide. There is still another class of oscillations called *seiches*, which have been already observed in the Swiss lakes, and for which a solution, in all respects satisfactory, has not been offered. Whenever the lakes are sufficiently free from the disturbing action of wind to permit observation, a quite regular series of small waves, or pulsations, can be detected, which have an interval of about ten minutes from impulse to impulse. These pulsations seem to occur almost without cessation on Lake Superior. Besides having tides in common with

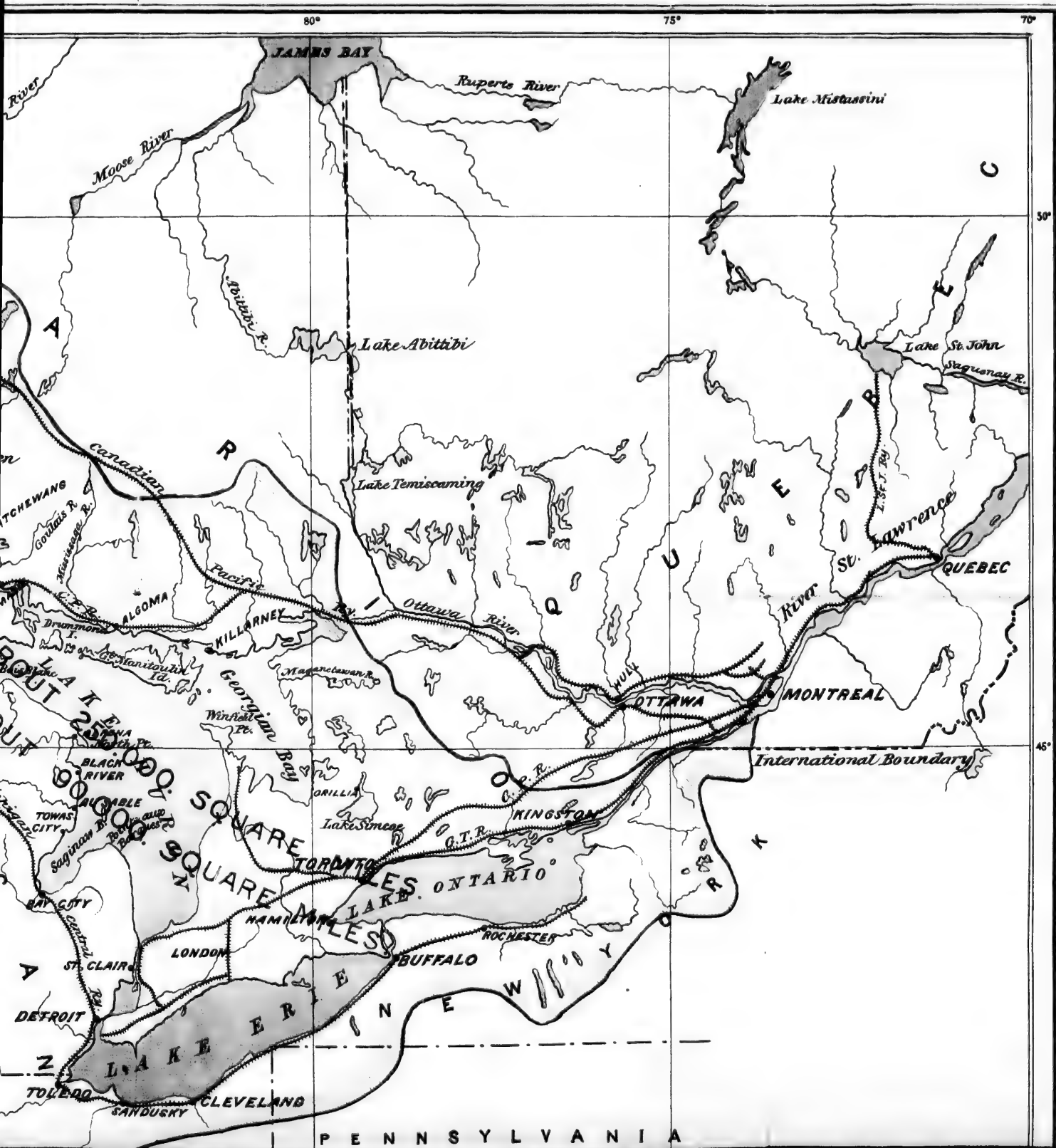
the ocean, the lakes have well-defined land and lake breezes, the breeze from the lakes landward commencing in summer at 8 or 10 o'clock a.m., and continuing until sunset, and the breeze from the land lakeward from 9 or 10 p.m. until sunrise.

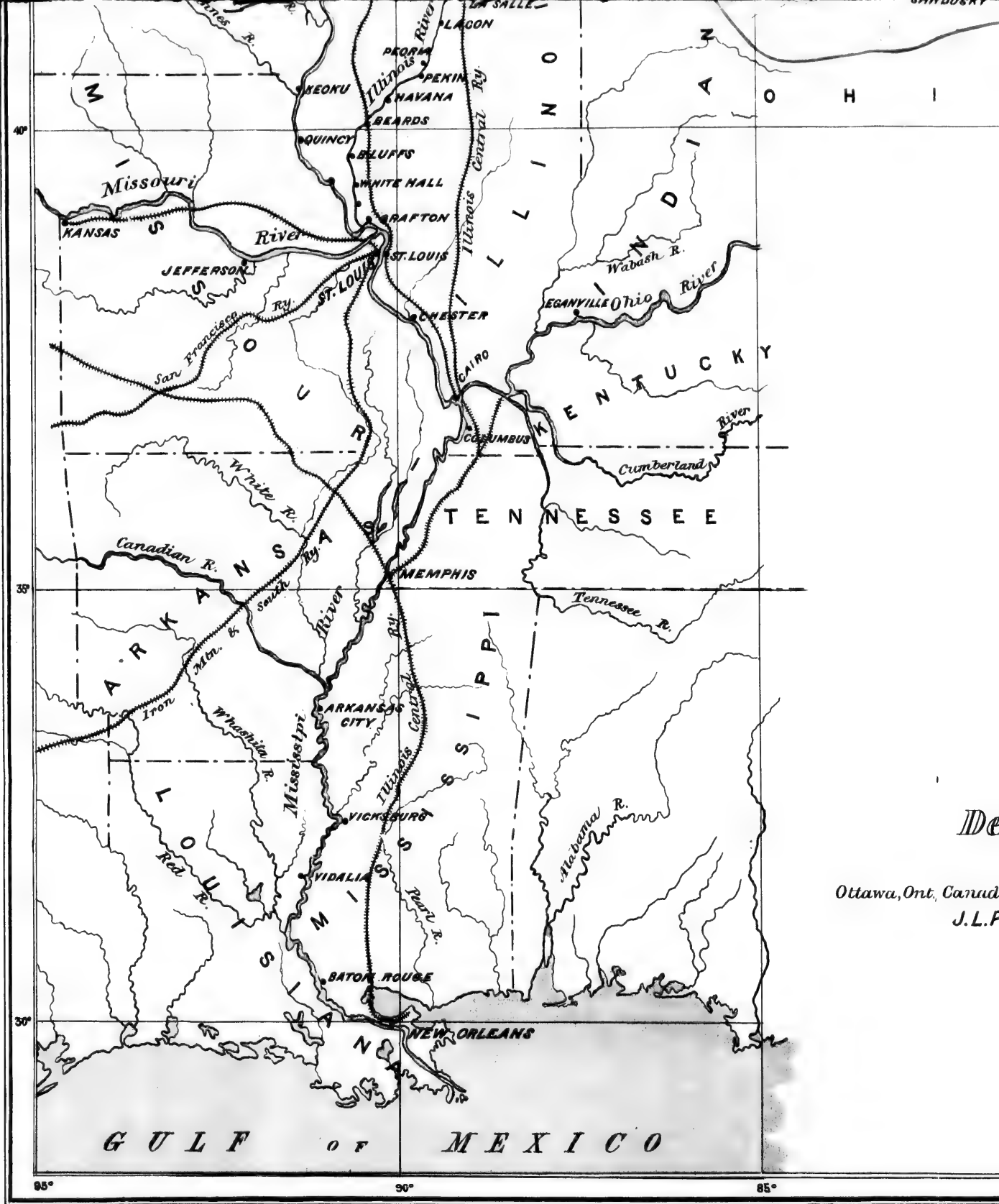
For about one-half the distance across the continent the waters of the St. Lawrence system divide the Dominion of Canada from the United States. The boundary line, beginning on the St. Lawrence in latitude 45 degrees, passes through the middle of Lake Ontario, Erie, St. Clair, Huron, the St. Mary's River and Lake Superior, to a point on its north shore, 124 miles east of Duluth and Superior, the western end of Lake Superior. Lake Michigan is wholly within the territory of the United States. These great lakes contain more than one-half the area of all the fresh water of the globe. They make up the largest system of deep water inland navigation on the globe. No other inland water may bear upon its bosom so vast a commerce, or touches, as this does, the vital interests of so many millions of men. Lying, in general direction, east and west between the 41st and 47th parallels, they penetrate the tide water on the St. Lawrence. The western extremity of the system, the head of Lake Superior, is 1,700 miles only from the waters of the Pacific. It is 2,384 miles from Belle Isle, at the mouth of the St. Lawrence, and 4,618 miles from Liverpool.

The range of this water system, it will be observed, is entirely within the limits of the north temperate zone, on the line on which population has most freely moved westward, where final settlement is most compact, and where climatic conditions insure the largest returns to capital and labor. Lake Superior, the head of the system, alone receives the waters of 200 rivers. One hundred and fifty miles northwest of Port Arthur and, Duluth are the fountains of three of the great drainage systems of the continent. Physical conditions there send flowing waters northward to the ocean through Hudson's Bay; southward, through the Mississippi Valley and the Gulf of Mexico, and eastward, through the lakes and the St. Lawrence. For commercial purposes, the northern drainage system has not yet been utilized; but flowing water will forever be a potent instrument of commerce, southward and eastward, between the interior and the Atlantic coast.

Such are the peculiar and the favoring physical conditions under which two great peoples of English tongue occupy, side by side, the North American continent from ocean to ocean, using in common this continental water-way, and by treaty stipulations interchanging with each other the use of improvements inside their respective boundary lines. From both sides, then, of this continental boundary line, inevitably and forever, will come here for transit into the world's commerce, the products of the vast plains and the mountain region of the far Northwest. On this line, also, to a large extent, will be made the commercial exchanges of the Pacific Slope, Australia, China and Japan.





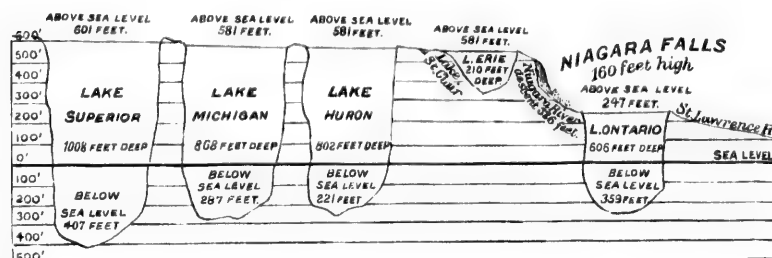


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Ottawa, Ont, Canada

J.L.F.

LONGITUDINAL SECTION  
OF THE GREAT LAKES AND CONNECTING RIVERS.



To accompany report on "Effect of Chicago Drainage Canal on levels of  
Great Lakes and connecting Rivers" by order of

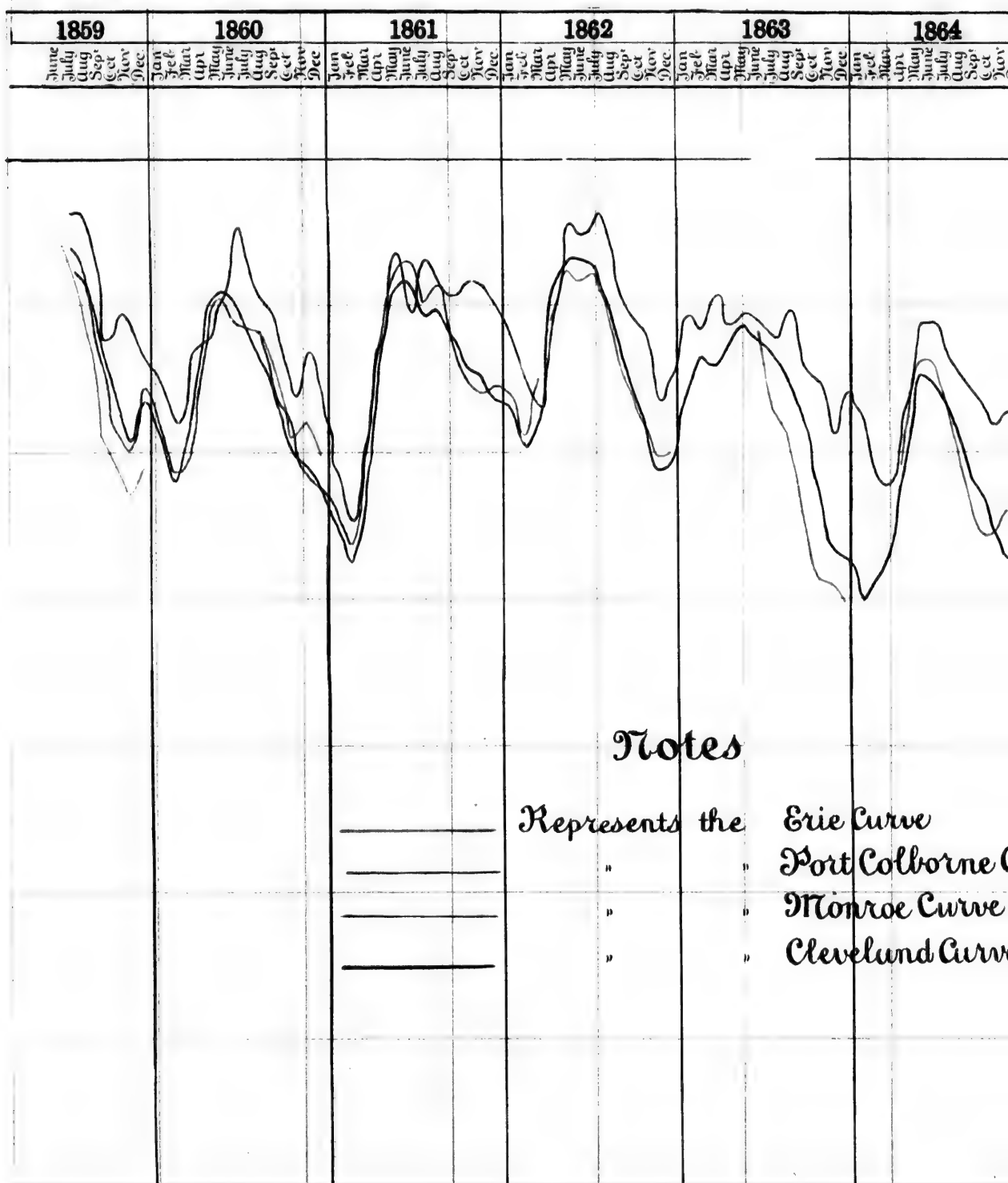
HONORABLE JOHN COSTIGAN,  
Minister of Marine and Fisheries  
Canada.

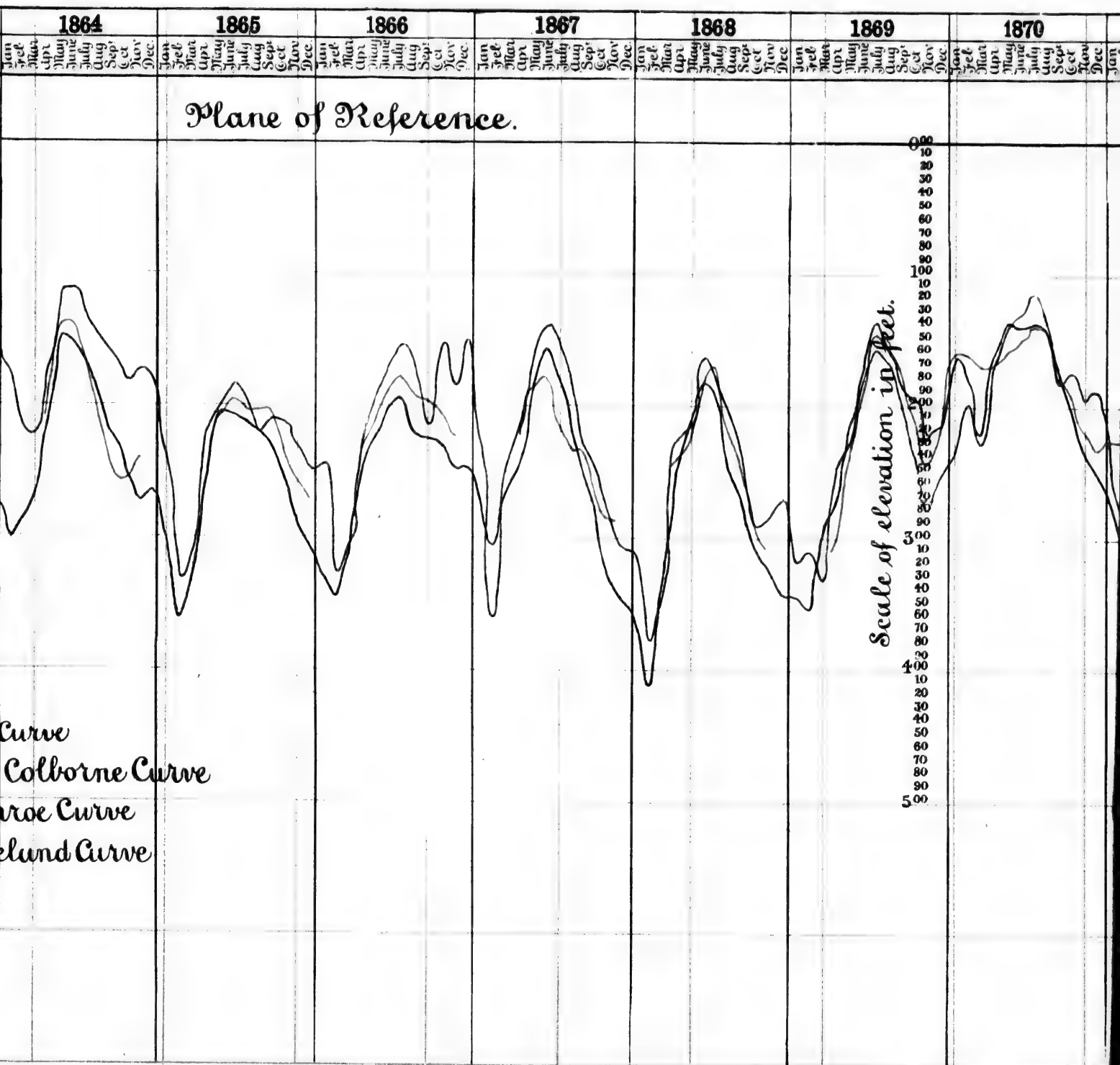
*Map Showing*  
*The Drainage Basin of the*  
**GREAT LAKES**  
*— with the —*  
*Des Plaines, Illinois and Mississippi Rivers.*

Ont., Canada, April 1896.

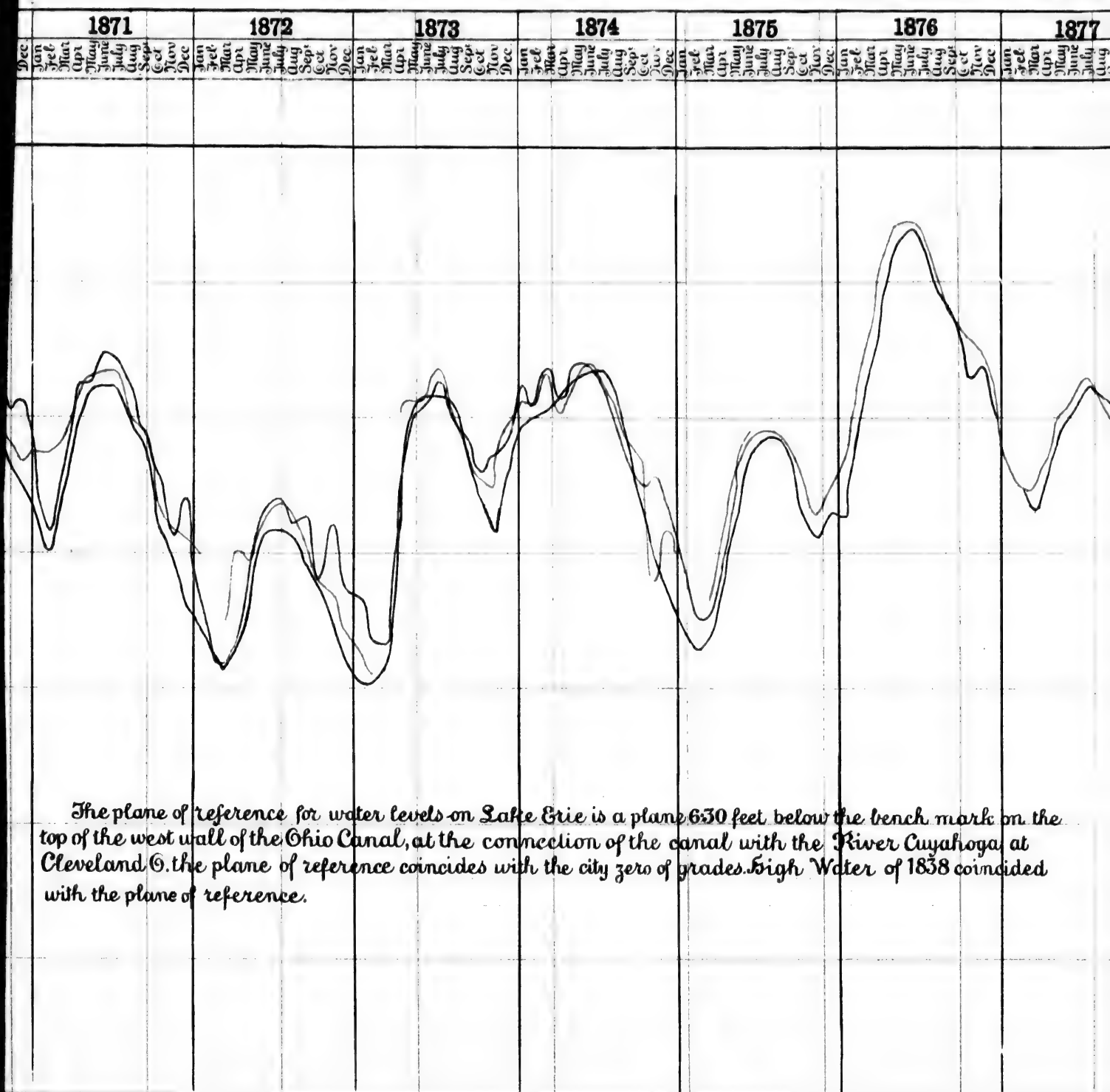
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SHEET, NO. 2.

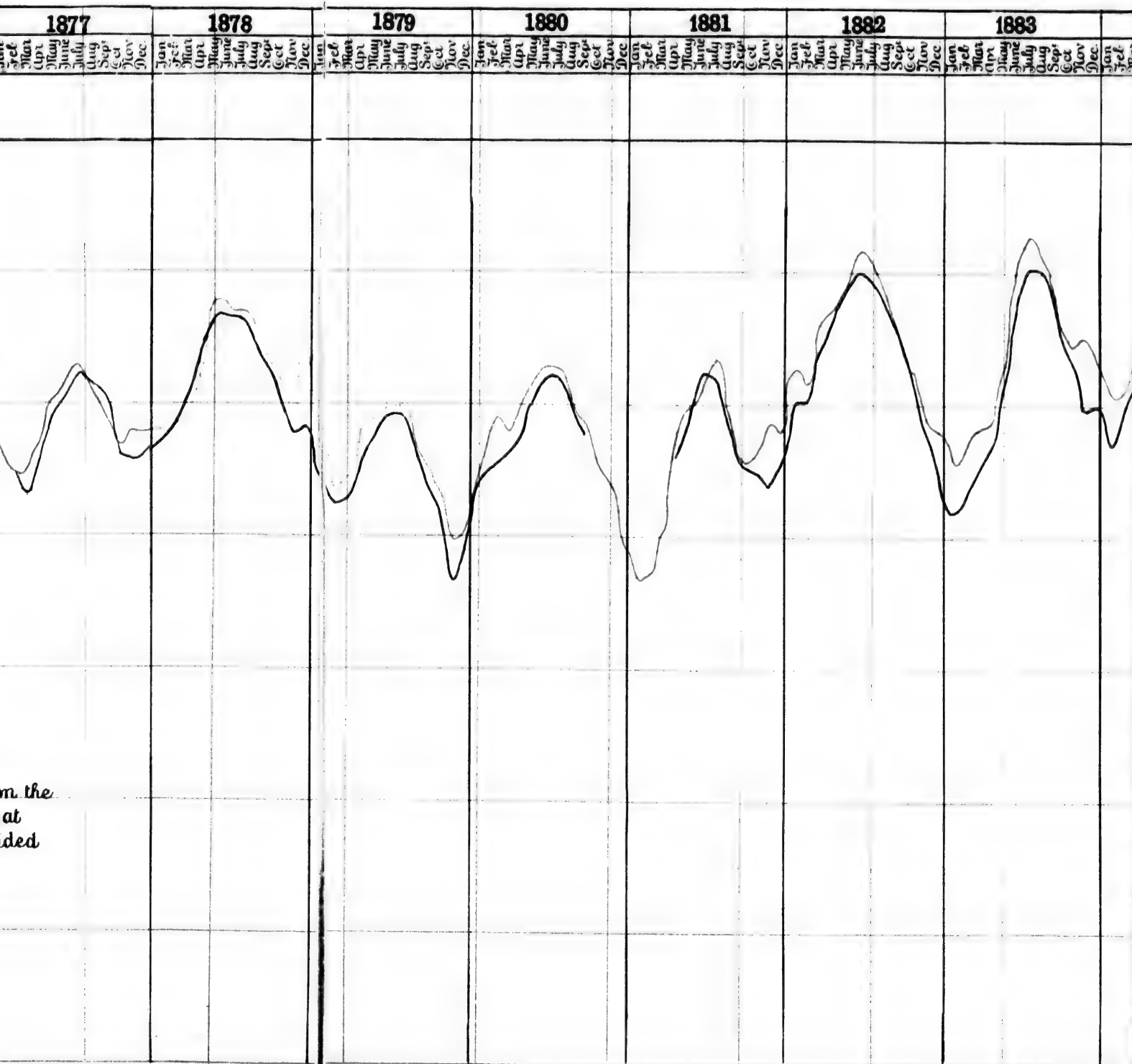




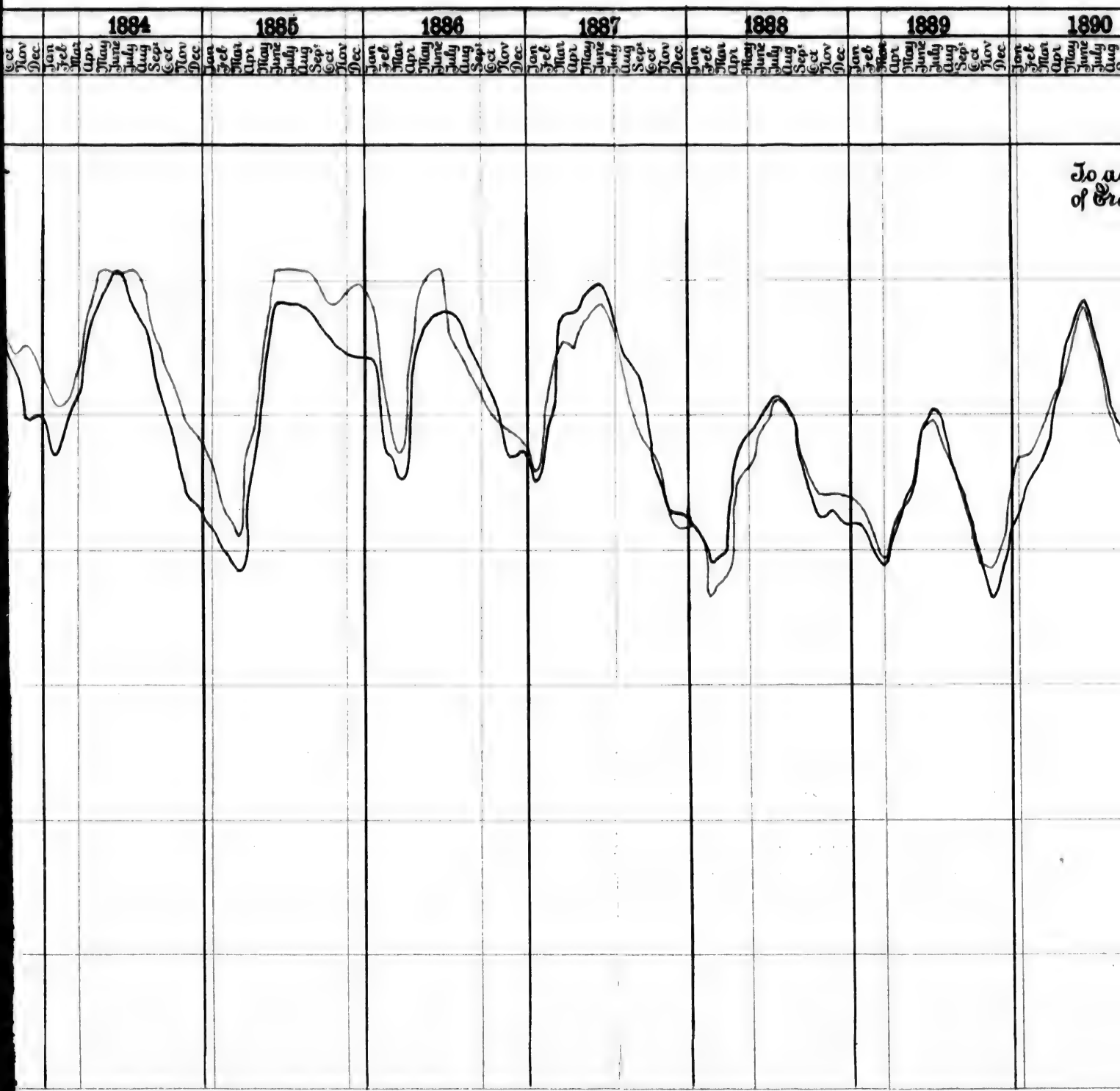
# Annual Water Level Curves Lak



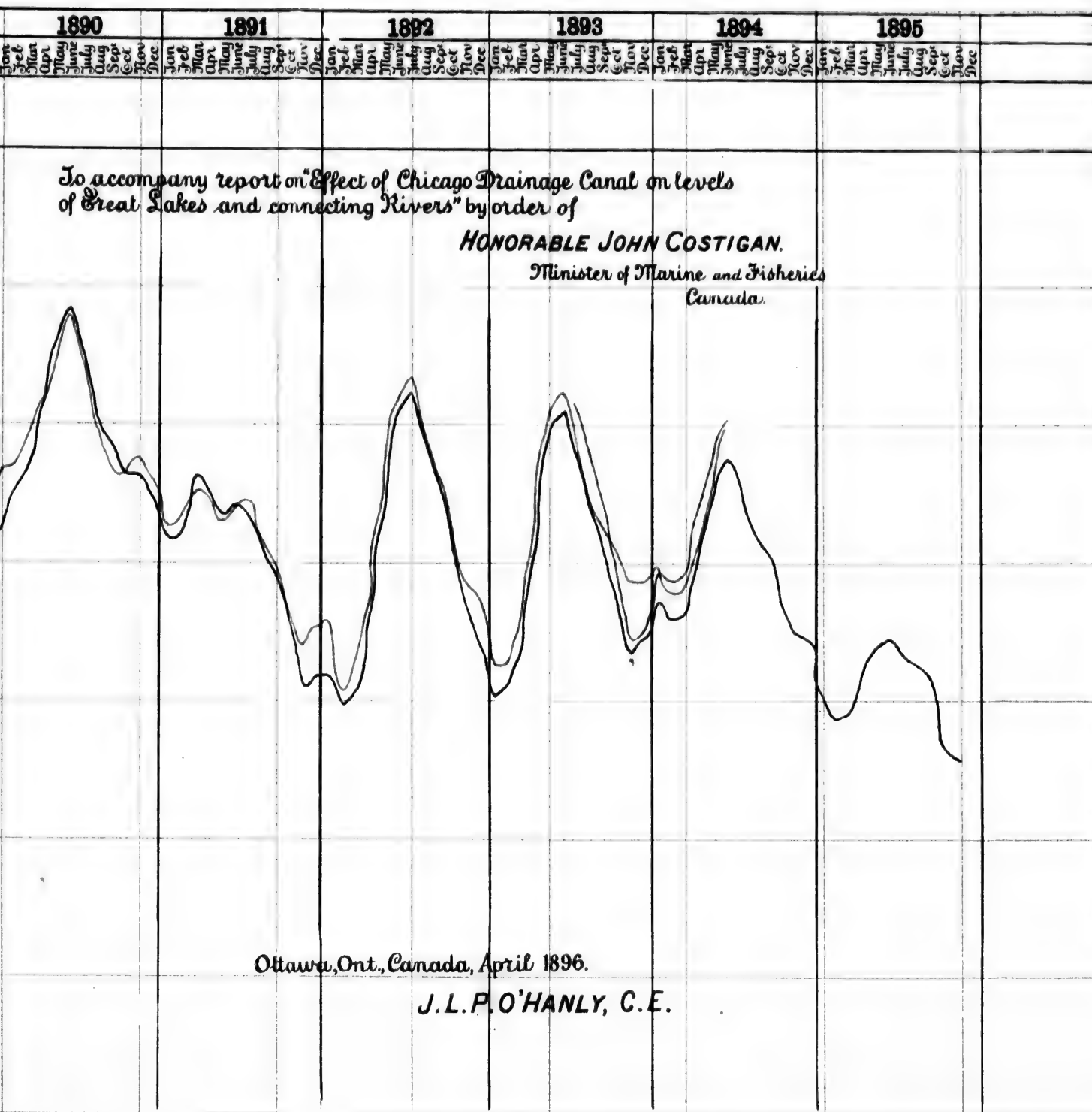
# Lake Erie.



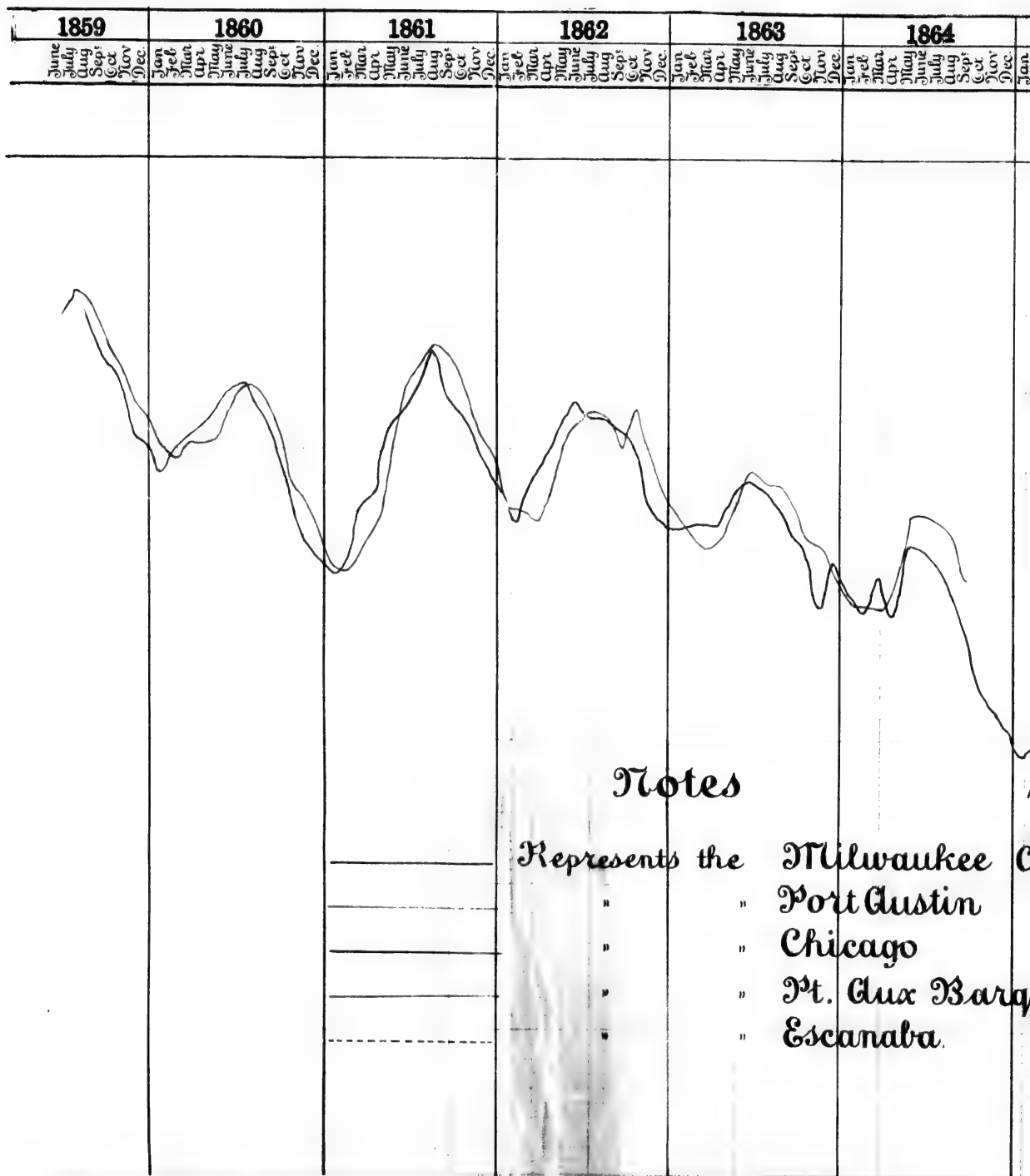
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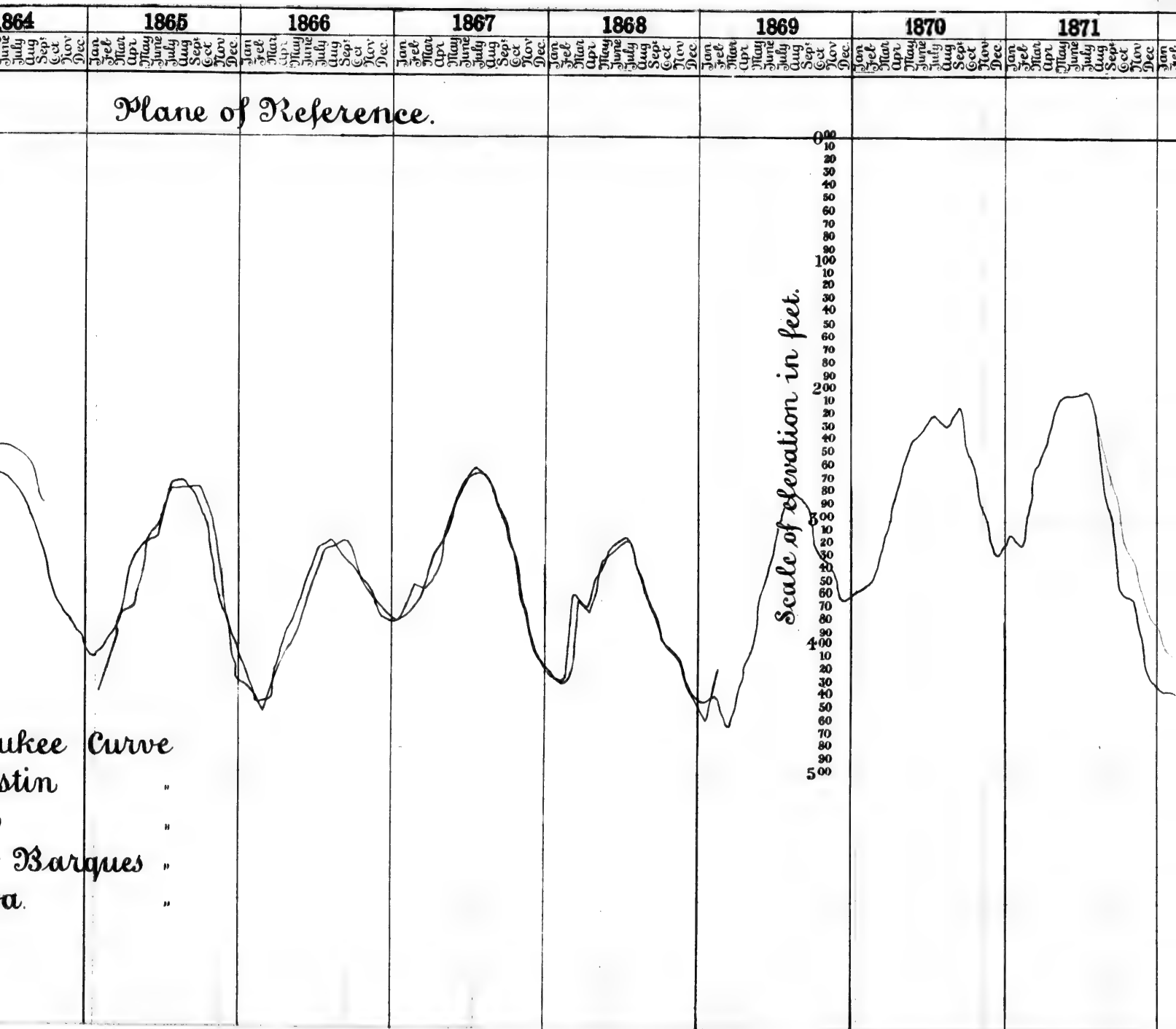


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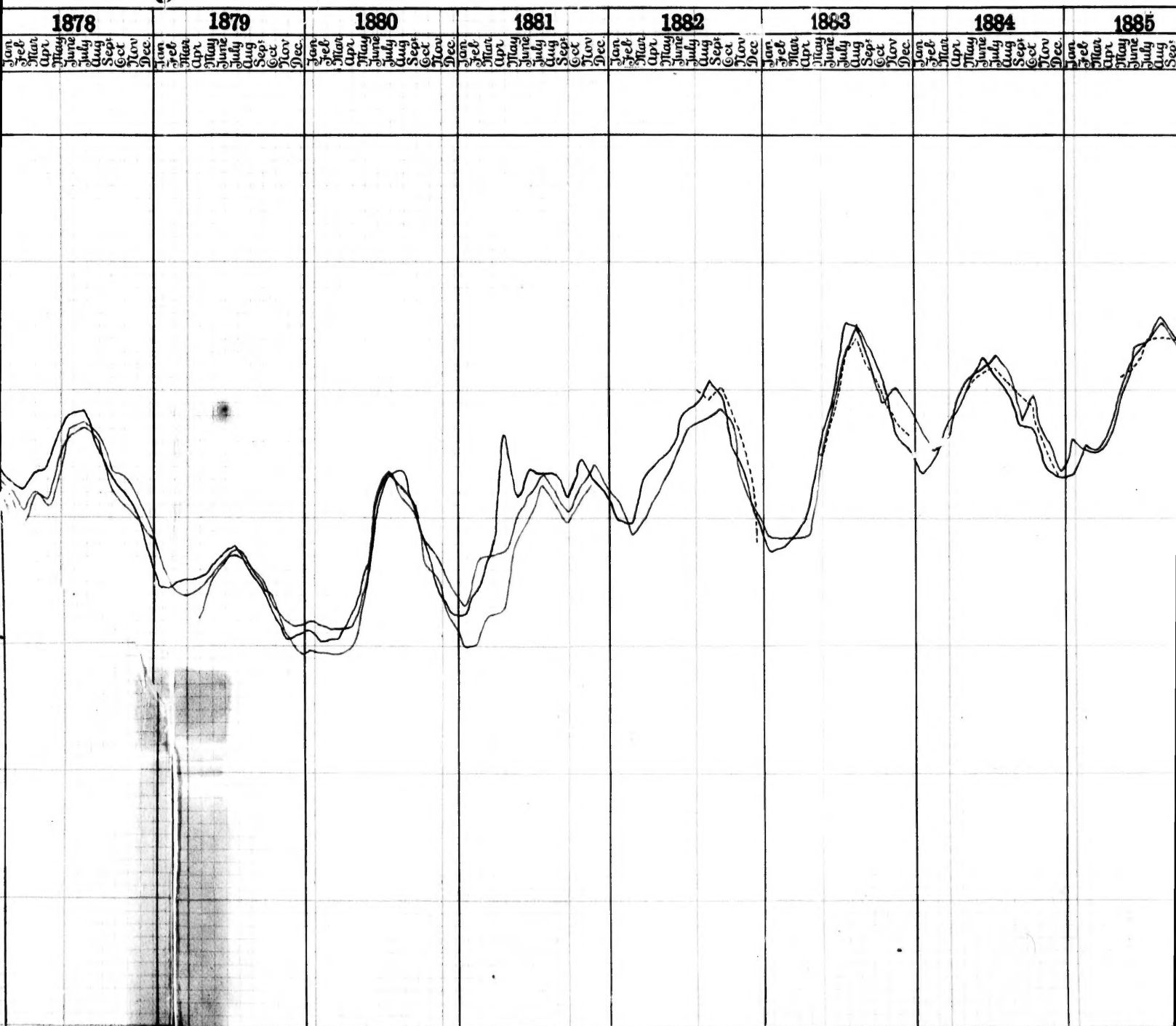
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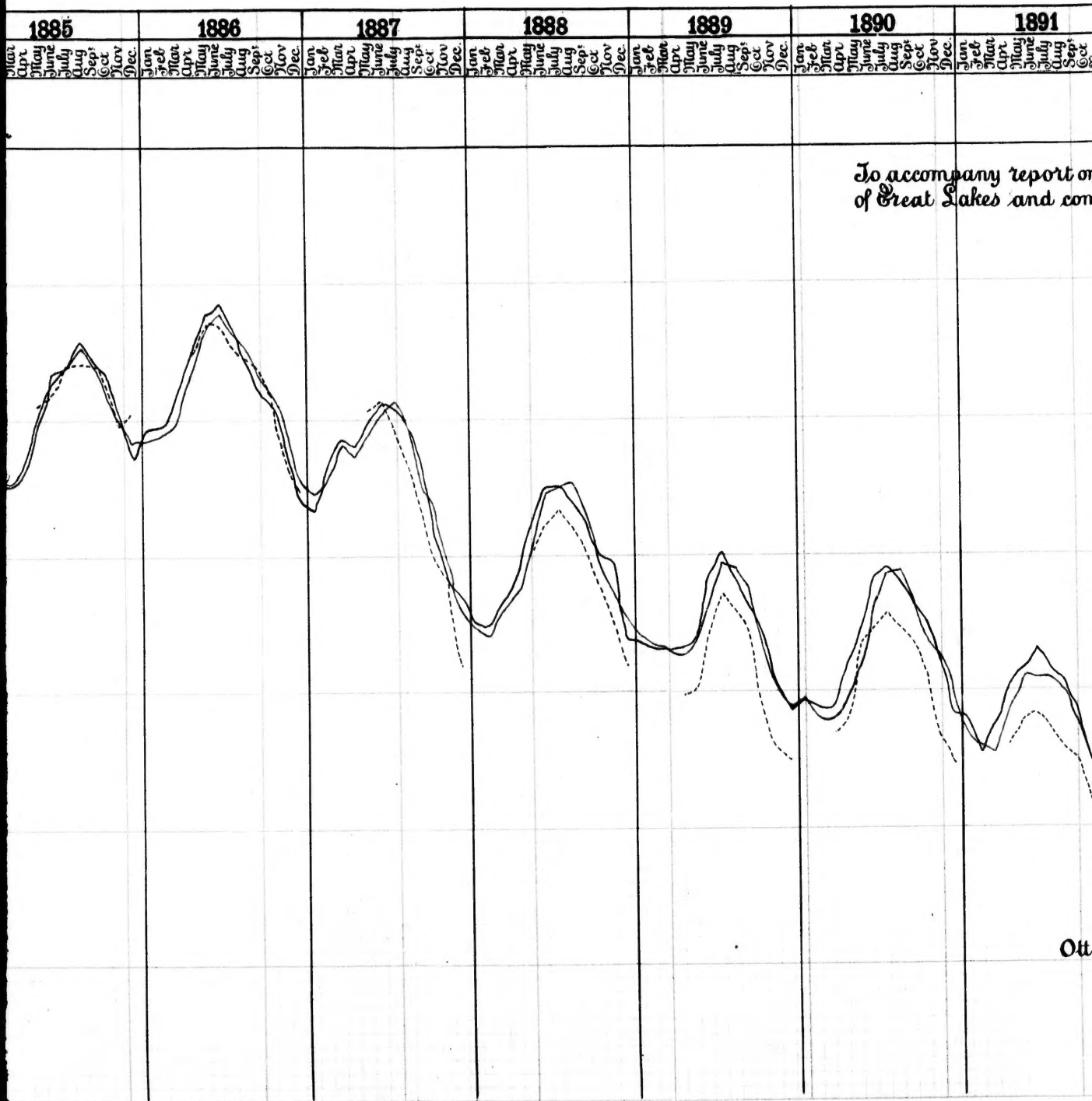






# Michigan and Huron.





To accompany report on  
of Great Lakes and com

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